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DETECTING BONE FUNCTIONAL ADAPTATION IN THE CAPITATE OF EXTANT HOMINOIDS

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Introduction

As a central component of the midcarpal and carpometacarpal joints, the capitate plays a primary role in primate hand biomechanics. Capitate morphology facilitates mobility of the midcarpal joint in suspensory apes, limits extension in knuckle-walking apes, and in humans stabilises the capitometacarpal joint for tool behaviours[1-3] (Fig. 1) Biomechanical loading of the capitate varies across taxa with respect to changes in hand and wrist postures associated with different locomotor and manipulative repertoires[4-6]. As a metabolically active tissue, internal trabecular bone is known to remodel over the lifetime of an individual, and has the potential to reveal patterns of in vivo loading[7].

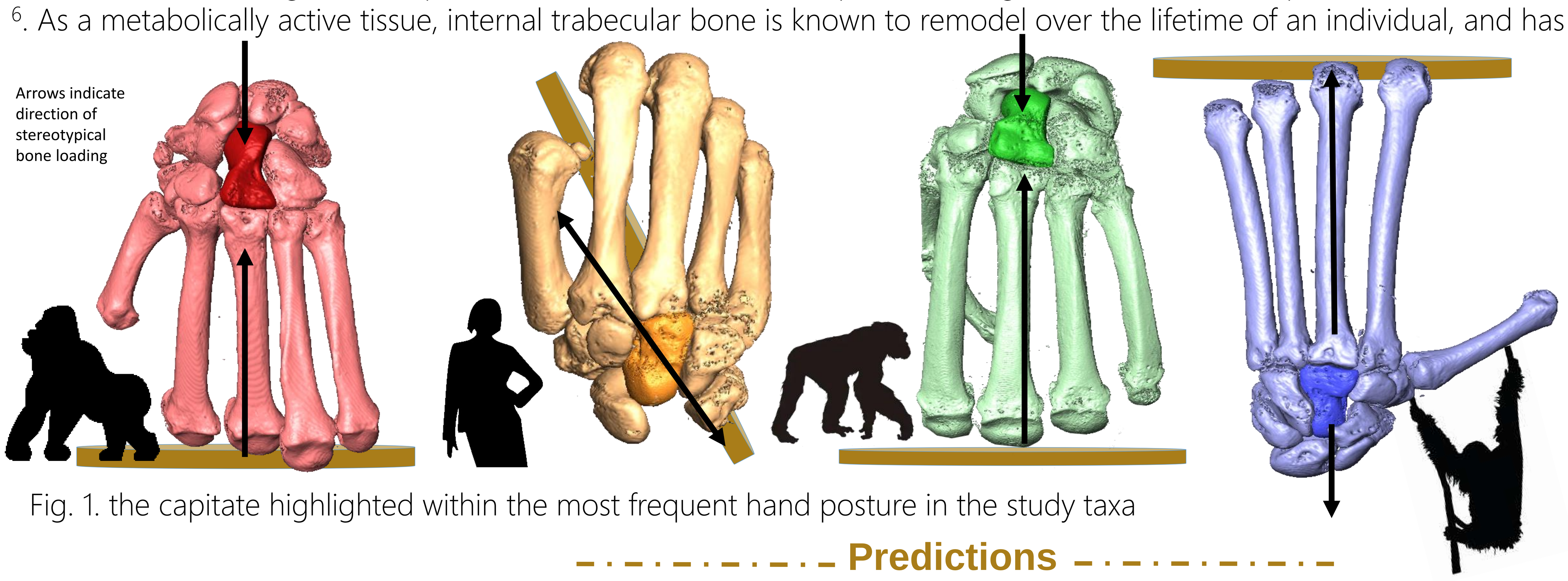


Fig. 1. the capitate highlighted within the most frequent hand posture in the study taxa

Methods

- trabecular structure related to strength (e.g BV/TV, DA, Tb.Th, and Ct.Th) was analysed in the capitate of extant apes to test whether bone architecture correlates with variation in predicted hand loading (Table 1).
- Capitates were μCT scanned (30-50 microns) and trabecular and cortical bone was analysed holistically in 3D using medtool[8] and BoneJ
- internal bone was segmented (Fig. 2a-b) and a tetrahedral mesh of each tissue was generated (c).
- Data was interpolated onto the individual 3D meshes for visualisation of BV/TV distribution (d).
- interspecific differences were tested in R using Kruskal-Wallis with post-hoc pairwise t-tests. Colour scales for each specimens were standardised by dividing by the mean.

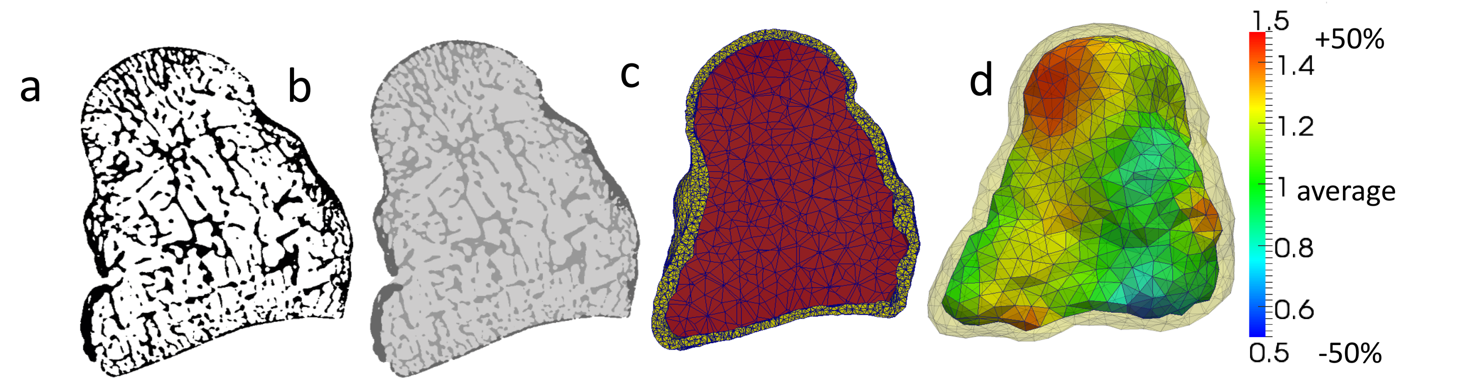


Fig. 2. Steps of trabecular and cortical bone analysis using medtool

Predictions

Genus	Hand Loading	Loading stereotypy	Cortical (Ct.Th) and Trabecular (Tb.Th) Thickness	Bone volume / total volume (BV/TV)	Degree of Anisotropy (DA)	Areas of BV/TV Concentrations
Gorilla n=16	Highest	Compression	Highest##	Highest##	High	Dorsal ridge
Homo n=30	Lowest	Compression	Lowest##	Lowest##	Intermediate#	MC3 styloid process#, trapezoid#
Pan n=14	High	Compression + Tension	Intermediate##	Highest##	High	Dorsal ridge#
Pongo n=13	Moderate	Tension	Intermediate##	Intermediate##	Lowest##	Homogenous#

Table 1. Study predictions: ## indicates strong and # some support was found for prediction

Results

Support for predictions (Table 1) are shown in the above table and below box-plots (Fig. 3). The Kruskall-Wallis analysis indicated that **measured parameters differ significant across the sample genera**. While some predictions were supported, the distribution of trabecular bone within the non-human apes did not consistently conform to predictions.

Gorilla and *Pan* dorsal ridge concentration:
- 37% of gorillas (n=6),
- 11% of bonobos (n=1)
- 60% of chimpanzees (n=3)

Patterns in *Pongo*
- 50% homogenous pattern throughout the capitate as predicted
- 50% concentration from the proximal most point of the capitate, running directly distal through the head.

Human BV/TV concentrations
- 43% (n=13) at trapezoid
- 50% (n=15) at MC3 styloid process
- 86% (n=26) showed a distinct oblique concentration across capitate head

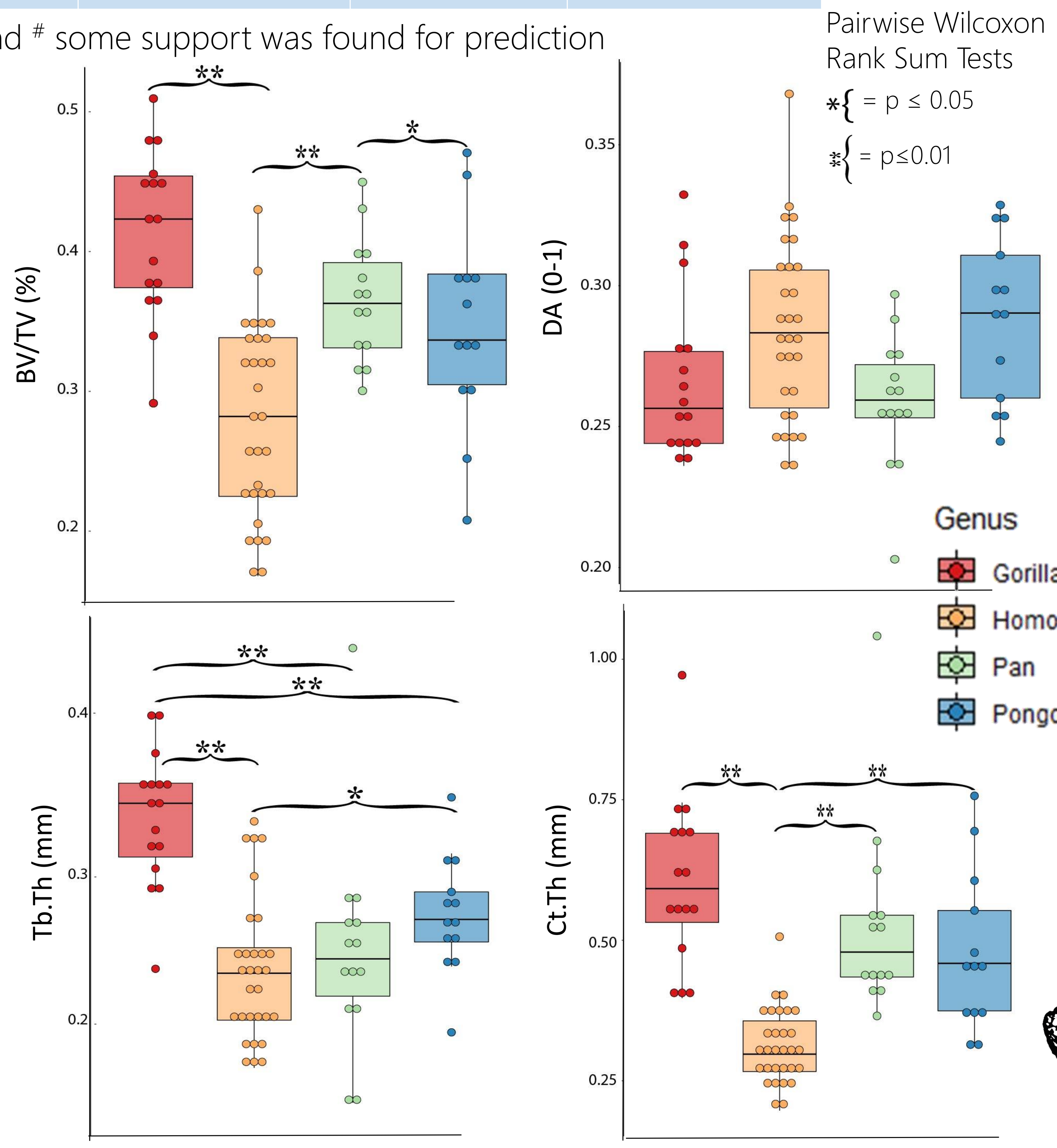
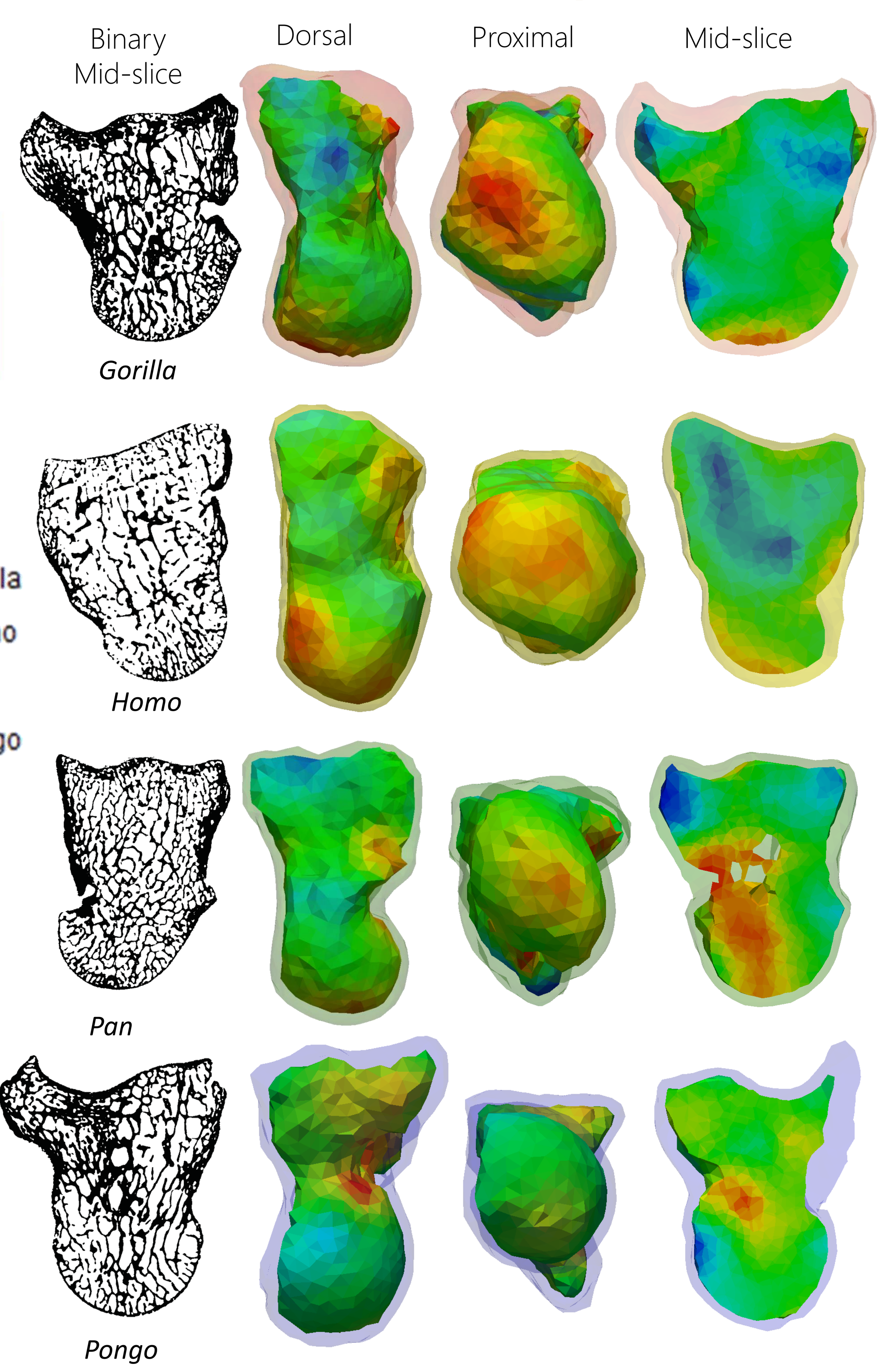


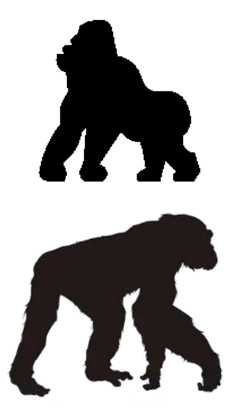
Fig. 3 Boxplots of each trabecular parameter and Pairwise results

Bone Volume Map Results



Discussion

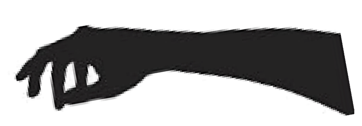
The almost ubiquitous presence of an oblique bone concentration across the capitate head coincides with the movement of the capitate during **the functional plane of the human wrist, the so-called Dart-Throwers Motion** (DTM)[9].



The differences in the dorsal ridge bone concentration between bonobos, chimpanzees and gorillas suggests dissimilar strain patterns in the wrist. Divergent use of knuckle-walking is reported in previous research across the species[10], therefore **peak mechanical strain likely differs across the hand**.

Orangutan results were generally consistent with predictions while also showing a large degree of variation. This is suggestive of a **diverse loading pattern during arboreal locomotion** and a mobile wrist joint.

Future Work



The DTM is hypothesised to be unique to humans thus this finding presents new avenues to study tool use and hand biomechanics in fossil hominoids.

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